Climate Friendly Alternative Fuel Vehicle Analysis

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Reference: D5334

1. Objective and Scope
2. Approach
3. Results
4. Summary and Conclusions

Motivation

- California's Vehicle Global Warming Pollution Law (AB1493) requires GHG emission reductions from passenger cars.
- Alternative fuels can provide GHG emission reductions.
- The objective of this project is to compare conventional and alternative fuel vehicles with respect to:
  - Consumer cost
  - Well to wheels GHG emissions
  - Fuel cycle criteria pollutant emissions (well-to-tank).
- Results can provide input for analysis of possible compliance scenarios.

Evaluation Matrix: Consumer Cost and Emissions

Fuels and Vehicles → **Screening** → **Cost Comparisons**

Fuel	Vehicle	Descriptor	MY 2009	
			Pass Car	Full-Size SUV
Gasoline	SI ICEV	Gasoline ICEV	✓	✓
Diesel	CI ICEV	Diesel ICEV	✗	✗
Ethanol (E85)	SI ICE FFV	E85 FFV	✓	✓
Biodiesel (B20)	CI ICEV	B20 ICEV	✗	✗
Biodiesel (100%)	CI ICEV	B100 ICEV	✗	✗
LPG	SI ICEV	LPG ICEV	✓	✓
LPG/Gasoline	SI ICEV	LPG/Gasoline	✓	✓
CNG	SI ICEV	CNG ICEV	✓	✓
Gasoline/Electricity	Plug-in HEV, 20 mi range	HEV 20	✓	✓
Electricity	Battery electric	BEV	✓	✓
Hydrogen	SI ICEV	H2 ICEV	✗	✗
Hydrogen/Gasoline	SI ICEV	H2 Bi-Fuel	✓	✓
Hydrogen	FCV	H2 FCV	✗	✗

Potential for
•Fuel + vehicle costs close to gasoline
• GHG reduction

• MY 2009 LDV, SUV
• Dedicated & Bi-Fuel

- Assumed automaker meets GHG limit by selling only alt fuel vehicles.
  - Vehicle does not include one-time development and certification costs
  - Fuel costs don't include transition costs
- MY 2009, sales start in 2008
- Vehicles not considered in 2008 timeframe:
  - Hydrogen fuel cell vehicle
  - Biodiesel vehicles
  - Battery electric vehicles

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How do FFV and Bi-Fuel Vehicle owners decide which fuel to purchase?

- Difficult to verify GHG compliance

Fuel	Motivation	Effort
Gasoline		
Ethanol		
LPG		
CNG		
Electricity		
Hydrogen		

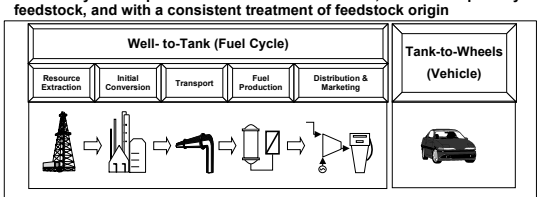
- FFV and Bi-Fuel Benefits
  - Fuel price flexibility
  - Fuel availability
  - Mitigates chicken/egg problem

Conventional Fuel Available
Fuel Cost Flexibility

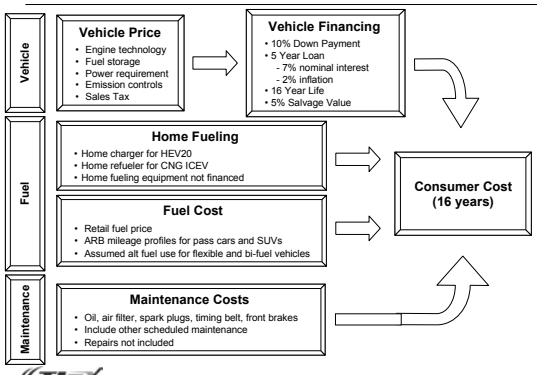
Alternative Fuels
Reduced Emissions
Fuel Cost Flexibility
Energy Security

Metrics
- Fuel Cost
- Fuel Availability
- Consumer Motivation

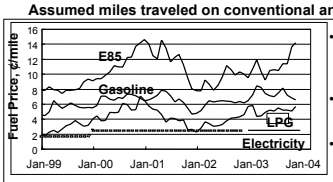
The fuel cycle is represented as a chain of modules, each with a primary feedstock, and with a consistent treatment of feedstock origin



- Emissions are estimated on a marginal basis for fuel consumed in California.
- Criteria pollutant emissions are counted in California.
- Fuel cycle emission sources include: fuel combustion, leaks, spills, and non-feedstock inputs (such as electricity).
- Emissions associated with production of capital equipment are a relatively small fraction of the fuel cycle and are not analyzed here.



Assumed miles traveled on conventional and alternative fuels…

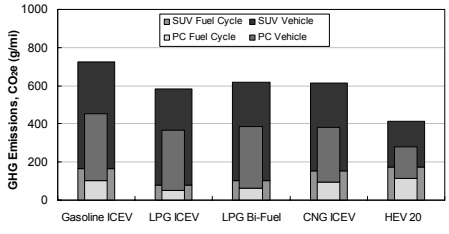


- Bi-fuel vehicles allow customer to minimize fuel cost and reduces infrastructure costs
- Alternative fuel use depends on cost savings and fuel availability
- Difficult to verify compliance

Fuel	Fuel Cost (% time cheaper)	Availability (# locations)	Assumed Here (% miles on alt fuel)
Gasoline	--	~9500[1]	--
Ethanol	0%	1[2]	**10**
LPG	97%	535[2]	**75**
Electricity	100%[5]	>1,000,000[3]	**31[6]**
cH2	0%	13[4]	**50**

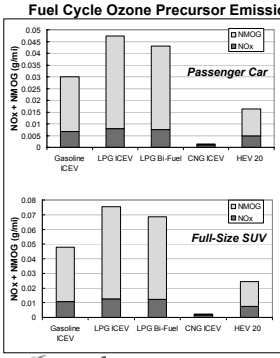
1. CEC Website 2. www.cleancarmaps.com 3. 500 public + 6.7 million owner occupied households (US Census Bureau) 4. www.fuelcells.org 5. Takes into account improved vehicle fuel use. 6. NPTS Mileage Weighted Probability per 2001 EPRI HEV Report.assumed HEV 20 battery replacement at 100,000 miles.

Fuel Cycle GHG Emissions



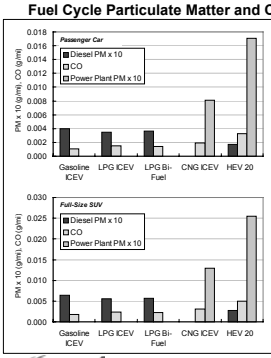
- Several alternative fuel options resulted in significant GHG emission reductions compared with a conventional gasoline vehicle.
- GHG reductions range from 15 to 20 % for LPG and CNG and 40% for HEV20s

Fuel Cycle Ozone Precursor Emissions



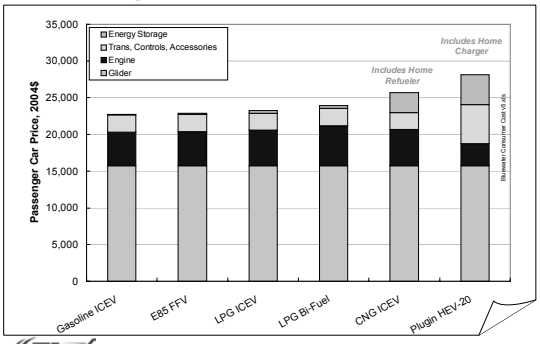
- NMOG emissions are primarily fuel spillage and fuel transfer emissions from liquid fuels.
- All alternative fuels except LPG have lower fuel cycle NMOG emissions
  - Due venting of LPG tanks during fueling. Hardware solutions exist to limit LPG venting.
- NOx emissions are from truck, ship, and rail car transport of liquid fuels.
- Other NOx emissions correspond to power plant emissions for gas processing and compression.

Fuel Cycle Particulate Matter and CO Emissions

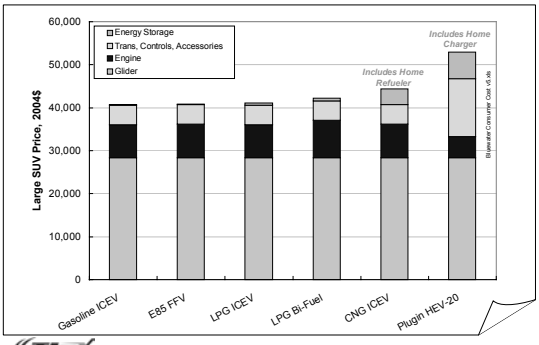


- Diesel PM emissions are from truck, ship, and rail car transport of liquid fuels. CO is also emitted from these diesel engines.
- PM from electric power plants is part of the fuel cycle for CNG, HEV20 power, and hydrogen
  - These emissions are not directly comparable to vehicle PM because of differences in the testing methods..

MY 2009 Passenger Car Prices



MY 2009 Full-Size SUV Prices

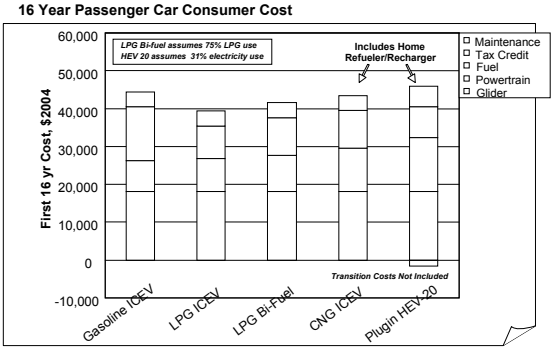


Fuel Price Summary

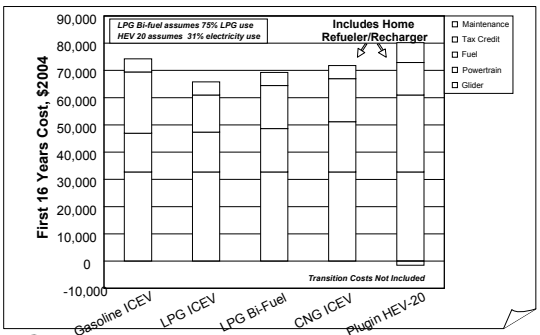
Fuel	Units	2004 Prices		MY 2009 Price Projections, $2004		
		2004$ Price	Comment	CEC/ARB	EIA % Δ on 2004 Price[7]	Used in Analysis
Gasoline	$/gal	1.72	Two year historic avg[1]	1.74	1.78	1.74
E85	$/gal	1.77	Two year historic avg[2]	1.55	1.80	1.76
LPG[3]	$/gal	1.06	Two year historic avg[4]	1.31	0.96	1.07
CNG	$/therm	1.03	California Tariff[5]	1.46	1.03	1.03
Electricity	¢/kWh	7.4	California Tariff[6]	11	7.0	7.4
Hydrogen[8]	$/kg	x	x	4.28	2.32	2.32

1. Average of 2001-2003 retail California reformulated regular grade gasoline, EIA.
2. Added transport, storage, marketing, distribution o&m, profit, taxes to average 2001-2003 wholesale ethanol price ($1.24). Assumes a blenders credit taken (52c/gal with blender at 39% tax bracket) rather than 5.2 cent excise tax exemption.
3. Because LPG moves with gasoline, applied the historic ratio of gasoline to LPG to determine 2008 LPG price
4. Added transport, storage, marketing/dist, o&m, profit, taxes to average 2001-2003 midcontinent spot LPG price (0.51 $/gal).
5. Average of SoCal Gas and PG&E NGV compressed gas tariffs for 2004.
6. Average of SCE, SDG&E, PG&E tariffs for home EV chargers. Assumes all chargin is offpeak, equal winter and summer charging, and 80% of PG&E charging is within baseline quantity.
7. Apply % change in EIA fuel price projections between 2004 and 2008 to 2004 prices.
8. Tiax Hydrogen Cost Model projection for local natural gas steam reforming. Includes sales tax, no excise tax.

16 Year Passenger Car Consumer Cost

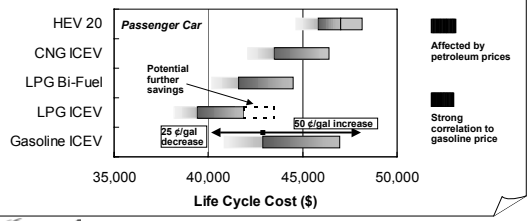


16 Year Full-Size SUV Consumer Cost



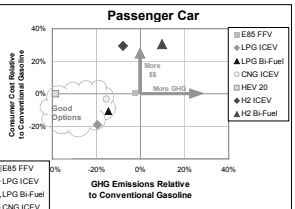
Many factors can affect the results of this study including the price of fuels.

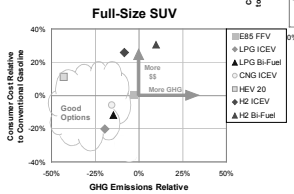
- Rising gasoline prices could make the cost comparisons more favorable for alternative fuels
  - LPG track gasoline prices, but an increase in gasoline prices may increase the advantage of LPG vehicles
  - Natural gas and power prices are less strongly correlated to gasoline prices.
  - Other fuel options may also be cost effective with rising gasoline prices.



Summary of GHG and Consumer Cost

- CNG, LPG Bi-fuel and LPG have lower GHG emissions and lower consumer cost.
- HEV 20 has the most GHG reduction but is higher cost than conventional gasoline ICEV.





- These cost and emission reductions compare to a baseline gasoline vehicle, not a vehicle meeting the AB1493 requirements.

Conclusions…

- Alternative fuel vehicles can provide significant GHG reductions at lower/equivalent consumer costs:
  - LPG ICEV and Bi-Fuel
  - CNG ICEV
  - Plug-in Hybrid (20 mile range evaluated)
- Flexible and Bi-fuel vehicles have many benefits but pose a compliance verification challenge.
- Gasoline prices strongly influence consumer cost result:
  - Analysis assumed $1.74 per gallon and well behaved costs in future.
  - At $2.25 per gallon, alternative fuel vehicle savings even larger and other options become cost competitive.